European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 93 30 7659

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
X A	US-A-4 150 400 (WONG) * column 4, line 28 - column 11, line 11 * ---	1,2,4 3,5-10	H04N1/40 H04N1/411
X,D	US-A-4 124 870 (SCHATZ ET AL.) * column 4, line 49 - column 9, line 41 * -----	1,2,4	
			TECHNICAL FIELDS SEARCHED (Int.Cl.5)
			H04N

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	19 January 1996	Materne, A

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

BEST AVAILABLE COPY

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 590 923 A3

(12) EUROPEAN PATENT APPLICATION

(88) Date of publication A3: 27.03.1996 Bulletin 1996/13

(51) Int Cl 6 H04N 1/40, H04N 1/411

(43) Date of publication A2: 06.04.1994 Bulletin 1994/14

(21) Application number: 93307659.8

(22) Date of filing: 28.09.1993

(84) Designated Contracting States: DE FR GB

(30) Priority: 28.09.1992 US 951961

(71) Applicant: XEROX CORPORATION
Rochester New York 14644 (US)

(72) Inventor: Smith III, Z. Erol
Palo Alto, California 94306 (US)

(74) Representative: Goode, Ian Roy et al
Rank Xerox Ltd
Patent Department
Parkway
Marlow Buckinghamshire SL7 1YL (GB)

(54) **Method for compressing, processing, and storing grayscale bitmaps**

(57) A method for image processing includes the steps of scanning an image (20) within a first grid of pixels (22). determining a grayscale value for each pixel scanned in the first grid of pixels. and. for each pixel scanned. activating a number of pixels of a second grid of pixels (25) corresponding to the grayscale value determined. Data representing the second grid of pixels can be compressed. and stored for use in facsimile transmission or photoreprographic image production.

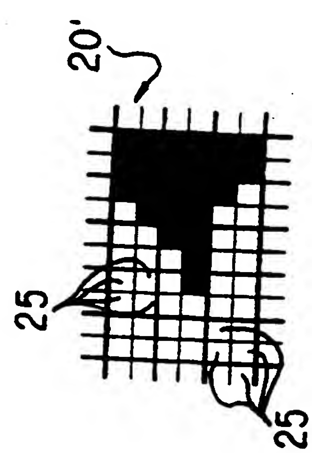

FIG. 4B

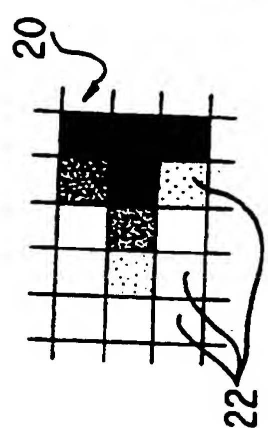

FIG. 4A

BEST AVAILABLE COPY

EP 0 590 923 A3

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number : **0 590 923 A2**

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number : **93307659.8**

(22) Date of filing : **28.09.93**

(51) Int. Cl.^{5} : **H04N 1/40**

(30) Priority : **28.09.92 US 951961**

(43) Date of publication of application : **06.04.94 Bulletin 94/14**

(84) Designated Contracting States : **DE FR GB**

(71) Applicant : **XEROX CORPORATION**
Xerox Square
Rochester New York 14644 (US)

(72) Inventor : **Smith III, Z. Erol**
924 Los Robles Avenue
Palo Alto, California 94306 (US)

(74) Representative : **Goode, Ian Roy et al**
Rank Xerox Patent Department, Albion House,
55-59 New Oxford Street
London WC1A 1BS (GB)

(54) **Method for compressing, processing, and storing grayscale bitmaps.**

(57) A method for image processing includes the steps of scanning an image (20) within a first grid of pixels (22), determining a grayscale value for each pixel scanned in the first grid of pixels, and, for each pixel scanned, activating a number of pixels of a second grid of pixels (25) corresponding to the grayscale value determined. Data representing the second grid of pixels can be compressed, and stored for use in facsimile transmission or photoreprographic image production.

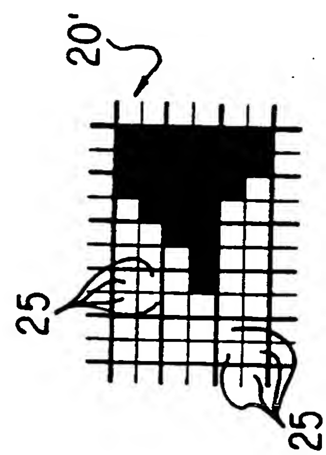

FIG. 4B

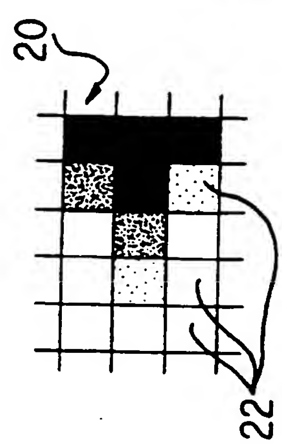

FIG. 4A

EP 0 590 923 A2

AD Cited in IDS for 07844/066001
Serial No. 08/547,562, filed 10/23/95

This invention relates to improvements in image processing techniques, and more particularly to an efficient, rapid, lossless method of compressing, processing and storing grayscale bitmaps using algorithms that are designed for binary images.

In the field of image processing, particularly in reprographic reproduction of an image or in the facsimile transmission of an image, the need for providing grayscale resolution of the image data is becoming of increased importance. Also, recently, with improvements in microprocessors and microcontrollers, and in digital information handling technologies, image data has been read and stored in digital form for processing.

Thus, typically, digital reprographic and image storage systems use a scanner to convert an input document to digital form. Such scanners, in their simplest form, compare the input image on a pixel-by-pixel basis to a predetermined threshold, such that pixels with brightness below the threshold are mapped to "1" (black) and pixels with brightness above the threshold are mapped to "0" (white). In more sophisticated systems, the scanners are capable of discerning various levels of gray in the image, and have a grayscale output, typically 4, 6, or 8 bits per pixel.

While the extension of binary scanners to images having grayscale values intermediate black and white can be realized with only modest technical and cost differences, the differences are much more substantial between binary output devices, such as displays and hard copy producing apparatuses, and those capable of reproducing gray-levels. This is especially true in such hard copy output devices as laser, ionographic, or inkjet printers. Until recently, most such devices were capable of rendering only binary bitmaps. For this reason, continuous-tone images, such as a photograph would be rendered as binary bitmaps for printing using halftoning techniques. For example, if the original were scanned at 300 spi (12 spots per mm) x 4 bit (16 level) gray, the image could be divided into 4 pixel x 4 pixel cells, the gray values of the pixels within the cell averaged, and then the 16 pixels in the cell turned on in proportion to the average gray value over the cell; for instance, a gray-level 8 out of 16 would be represented by blacking 8 of the 16 pixels in the cell.

While grayscale hard copy output devices are relatively rare, it has long been known in the bitmap display art that the legibility and apparent image quality of an arbitrarily-shaped image (such as typed characters, line-art, etc.) is improved by the technique of anti-aliasing. Anti-aliasing provides a method of presenting bi-level images on finite-resolution bit-mapped printers or displays with improved image quality by using intermediate gray-levels for pixels at the edges of features. More particularly, by this technique, an image can be rendered to a grayscale display of 50 spi (2 spots per mm) x 5 levels of gray by calculating what the text or image would look like at 200 spi (8 spots per mm), grouping pixels into 2 x 2 cells, counting up the number of pixels which are on, and mapping this to the gray-value of the 50 spi (2 spots per mm) image. When the image to be rendered is not in vector form (such as typed characters or line-art) but rather is already in high-resolution binary bitmap form, this high-resolution binary to low-resolution grayscale rendering is called inverse halftoning.

Now, recently, hardcopy output devices have begun to appear that are capable of reproducing a few levels of gray, rather than just black or white. One example is a copier/fax that has an 8 bit (256 level) scanner and can reproduce 6 levels of gray in its printout. Even if the original image scanned has no regions of intermediate gray, only black marks on white paper, for example, the apparent image reproduction quality is still improved by grayscale printing because the "jaggies" introduced by the finite spatial resolution of the scanner are softened using gray on partially occluded pixels. If the region does have regions of intermediate gray (such as a photograph or the like), these regions are usually better reproduced by halftone techniques than just mapping each pixel into the limited number of printable gray values. Thus, such digital reprographic systems might be thought of as printing anti-aliased images, whether the input image is monochrome or continuous-tone.

A key problem faced by systems such as the digital copier/fax mentioned above is how to efficiently store the scanned images of pages to support fax or electronic collation functionality. While compression techniques such as CCITT Groups 3 or 4 [G3 or G4] are both lossless and efficient for compressing binary images (i.e., the bitmap produced from a thresholded or half-toned scanned image), they are much less efficient at compressing grayscale data. In typical compression techniques, such as in CCITT G4, the most significant bit of the binary word represents the gray-level of each image pixel. However, such techniques do not efficiently compress the less significant bits that are important in grayscale applications. For these, special techniques exist (e.g., JPEG) which tend to be complex, slow, and sometimes lossy. Custom hardware accelerator ASICs for G4 are far more wide-spread and far less expensive than JPEG.

For example, considering a 2-bit gray printing process, when a multipage document is being copied, it is desirable for the compressed bitmap to be stored in system RAM. If gray-level 3 "11" is black and gray-level 0 "00" is white, then the most-significant-bit will look like the old binary image, and will compress well However, the least-significant-bit will look like the regular image with a white line drawn around character outlines. This LSB bitmap will not compress as well. Thus, storing the 400 x 2 G3/G4 image takes more than twice the space of the 400 x 1(MSB) bit image.

The compressed version of the second most significant bitplane is 2 to 3 times as large as the most significant bit plane because the transition from white to black in the original image, once sampled by the scanner, involves the transition from gray-level 0 (binary 00xxx) to gray-level 1 (binary 01xxx), then 2 (binary 10xxx), then gray-level 3 (binary 11xxx). Thus the most-significant bit is 0, then 0, then 1, then 1, while the 2nd-most significant bit is 0, then 1, then 0, then 1 as the scanner sweeps across the white to black edge. The G4 technique uses 1 Huffman code per transition from pixel-on to pixel-off or vice versa, and the 2nd-most-significant bit map has 3 times as many transitions as the edge is swept across.

Other grayscale compression approaches exist. For example, one approach is the so-called "Gray codes" (see, for example, Logic Design with Integrated Circuits, William E. Wickes, (John Wiley & Sons, New York, 1968) p 14). Another approach is described in the JPEG/MPEG standards. Gray codes have the advantage of being lossless, but would not enable standard G4 compressor/decompresor algorithms-/chips to be used without special adaptations; JPEG/MPEG are, in general, lossy and often introduce unwanted artifacts in images of fine text.

Techniques for up-conversion of low-resolution gray to high-resolution binary are also known, and used in products of the Xerox Corporation, like the Docutech or the 7650 scanner, in which the scanner actually scans at 400 spi gray and interpolates to 600 spi binary.

Reference is also made to K.Y. Wong and B. Schatz, in Graphical and Binary Image Processing and Applications, J. C. Stoffel, ed., (Artech House, Dedham MA, 1982); and US-A-4,124,870.

In light of the above, it is an object of the invention to provide an efficient, rapid, lossless method for compressing, processing, and storing grayscale bitmaps using algorithms that are designed for binary images.

In accordance with a broad aspect of the invention, a method for image processing is presented that includes the steps of scanning an image within a first grid of pixels, determining a grayscale value for each pixel scanned in the first grid of pixels, and, for each pixel scanned, activating a number of pixels of a second grid of pixels corresponding to the grayscale value determined.

Data representing the second grid of pixels can be compressed, and stored for use in facsimile transmission or reprographic image production.

In accordance with another broad aspect of the invention, a method is presented for image processing. The method includes scanning an image to produce a digital representation of the image at a first resolution and with a predetermined number of grayscale values. The digital representation of the image is converted to a digital representation of an image having an increased resolution at least as great as the first resolution times the base-2 logarithm of a predetermined number of grayscale values, and having only 2 grayscale values. The converted digital representation is then compressed and stored. The stored data can be used in facsimile transmission or reprographic image production.

The invention thus provides an improved technique for enabling the efficient compression of the less significant bits in grayscale bitmap applications.

The invention also provides an improved method for compressing successive bit-planes when operating on anti-aliased images, particularly in facsimile and reprographic applications.

The invention also provides a lossless means for storing grayscale bit maps using compression algorithms which are typically used for binary images, such as G3 or G4.

The invention also provides a method for transmitting data or storing data that requires essentially half the transmission time or memory space than prior data storing and transmitting techniques.

The invention is illustrated in the accompanying drawing, in which:

Figure 1 is a diagram of four grayscale values and their binary representations in forming grayscale images thereof.

Figure 2 is an image having the four grayscale values of Figure 1 that is desired to be stored and processed.

Figure 3A is a binary image produced using the least significant bit values of the grayscale values of the image of Figure 2, using prior art techniques.

Figure 3B is a binary image produced using the most significant bit values of the grayscale values of the image of Figure 2, using prior art techniques.

Figure 4A is a grayscale image having a resolution of 400 spi X 2 bits (4 grayscale levels), that is desired to be stored and processed.

Figure 4B is a binary image formed of the image of Figure 4A, having a resolution of 800 spi X 1 bit (2 grayscale levels), produced in accordance with the method of the invention.

And Figure 5 is a block diagram illustrating the steps of processing a grayscale image in accordance with the invention.

As will become apparent, the invention is particularly useful in processing an image that has multiple grayscale values. An arbitrary image having the four grayscale values shown in Figure 1 is depicted in Figure 2. The image of Figure 2 is depicted as it might be processed by a scanner or other device known in the art, and is partitioned into pixels 12, each of which having a particular grayscale value.

The four grayscale values shown in Figure 1 are numbered 0-3, representing increasing levels of black from white. Thus, the first level 0 is white, and, when mapped to a two-bit binary value, has a grayscale val-

ue of "00". The black level maps to the two-bit binary value "11", and the two intermediate gray-levels map to binary values "01" and "10". Of course, any number of grayscale values can be defined, four being described as being merely exemplary.

As mentioned above, in the past, one technique that has been employed in the processing of an image such as that of Figure 2 has been to generate a plurality of bit planes, each comprising the values at respective bit levels of grayscale information. Thus, in accordance with the prior art, as shown in Figures 3A and 3B, the image of Figure 2 would be mapped into the respective least significant bit plane shown in Figure 3A and most significant bit plane shown in Figure 3B. It is noted that the least significant bit map of Figure 3A has a "ghost halo" surrounding the image, and that the black values and an intermediate gray value map to the same black level. The combination of the bit maps of Figures 3A and 3B do not compress efficiently, using standard image compression techniques such as CCITT techniques G3 and G4.

On the other hand, the present invention provides a novel, substantially lossless method for storing grayscale bitmaps using compression algorithms that are normally used for binary images, such as G4. In the case of G4, it is twice as efficient as the technique of compressing successive bit-planes (i.e., the binary bitmaps of the most-significant bit, next-most-significant bit, etc.) when operating on anti-aliased images. This halving of memory requirements equates to halving the telephone charges for facsimile transmissions or halving the required RAM or disk space for digital copiers or image storage systems.

With reference now to Figures 4A and 4B, an image 20 to be processed is shown in Figure 4A. Again, the image is an arbitrary image, and, in the embodiment illustrated, has four grayscale levels as defined in Figure 1, but any number of grayscale values could be employed. The pixels 22 of the image 20 have a resolution of, for example, 400 spi (16 spots per mm). Thus, the resolution of the image 20 of Figure 4A is referred to herein as 400 spi x 2, representing, therefore, a resolution of 400 spi (16 spots per mm) having four grayscale levels.

In accordance with the invention, as explained in conjunction with the flow chart of Figure 5, the image 20 is scanned 50. The grayscale value of each pixel is determined 52. Then, the image 20 is mapped onto a binary grid of increased resolution 53, to produce an image 20' as that shown in Figure 4B. The image 20' is of increased resolution; in the embodiment shown it is twice that of the image 20 of Figure 4A. Thus, for each pixel 22 of the image 20 of Figure 4A, four pixel portions 25 of the image 20' exist.

As each of the pixels 22 of the image 20 of Figure 4A is mapped to the grid of higher resolution to form the image 20' of Figure 4B, the binary values of each of the pixels 22 of the image 20 are used to determine the number of pixels in the image 20' that are blackened. Thus, for example, a black image having a two bit binary value of 11 is represented by all four pixel portions of the image of increased resolution 20' being blackened. A gray-level having a two bit binary grayscale value of "10" maps to three of the four pixel portions of the image of increased resolution being blackened. A grayscale level having a two bit binary grayscale value of "01" is mapped to blacken only one of the four pixel portions of the image 20' of increased resolution. A grayscale value of white, represented by the two bit binary number "00" maps to no pixel portions of the grid of Figure 4B being blackened. It will be appreciated that although a two bit binary value representing four grayscale values has been illustrated in Figures 4A and 4B, any number of grayscale values can be mapped to a higher resolution grid. In such case, the mapping requires that each pixel of the original image map to a number of pixel portions that correspond to or are larger than the number of grayscale levels in the original image.

Thus, the image 20' of increased resolution as a binary image that can easily be compressed 54 using standard CCITT techniques such as G3 or G4, or other compression technique. The compressed image can then be stored 55 for subsequent use, such as to produce reprographic copies or facsimile transmission, or the like, or immediately transmitted 56 for decompression 58 and processing 59. In the stored image case, the stored image merely needs to be retrieved 57 and decompressed 58 and processed 59, as desired.

When the image is to be decompressed, for example, an 800 spi (32 spots per mm) image can be decompressed 2 lines at a time, grouped into 2 x 2 cells. The printer gray-level is then established by mapping the counted density in the cell (5 possible levels for a 2 x 2 cell) into the printable levels (4 in the embodiment illustrated).

More particularly, in a system having a 400 spi (16 spots per mm) scanner whose output is used to compose a 400 spi (16 spots per mm) x 2 bit anti-aliased image for processing, the image can be stored most efficiently in memory for reproduction, facsimile, or network transmission by first up-converting it to 800 spi x 1 and then compressing it, using, for example a G4 technique. If the image is to be printed, for example, as a part of a reprographic process, the higher resolution image can be retrieved from memory, decompressed and inverse halftoned down to the print resolution of the particular machine employed. Or, for example, if the image is to be transmitted via facsimile, the compressed image can be retrieved from memory, transmitted, then decompressed for display 61 or hard copy generation 60.

The method of the invention, furthermore, can be used to enhance the image reproduction capabilities

of reprographic machines that have different resolution scanning and copy or printing reproduction capabilities. For example, if a particular hard copy device has a scanning and reproduction resolution of 400 X 3, a digital representation of the image can be converted to a higher resolution, for instance of 1200 X 1. If another copier, or printer, has, for instance, a different resolution, such as 600 x 1, then interchange from the lower (400, gray) to higher (600, binary) resolution machine can be made by decompressing the intermediate (1200) very-high-resolution image with every other pixel and every other line used to compose the 600 x 1 image for the higher resolution machine, thereby introducing minimal image distortion.

It will be appreciated that the method of the invention is not limited to reprographic or facsimile systems. It is useful wherever images are intended to be rendered on a grayscale output device, such as a grayscale display of an image-retrieval system, or the like.

It will be also appreciated that the technique of the invention is most efficient for anti-aliased images, that is, images where gray valued pixels are only found in the sweep between black and white. This technique would not be as efficient if the region were, say, uniformly at gray-level 2 (binary "01") out of 4 grayscale levels.

Claims

1. A method for image processing, comprising:
   scanning an image (20) within a first grid of pixels (22);
   determining a grayscale value for each pixel scanned in said first grid of pixels; and
   for each pixel scanned, activating a number of pixels of a second grid of pixels (25) corresponding to the grayscale value determined.

2. The method of claim 1 wherein said first grid of pixels represents an image of first resolution, and said second grid of pixels represents an image of second resolution at least as large as the resolution represented by the first grid of pixels times the base-2 logarithm of the number of grayscale values that can be detected in said first grid.

3. The method of claim 2 wherein the resolution of said first grid of pixels is about 400 spi (16 spots per mm), and the number of grayscale values is 4, and wherein the resolution of said second grid of pixels is about 800 spi (32 spots per mm), and the number of grayscale values is 2.

4. The method of any one of claims 1 to 3 further comprising compressing the second grid of pixels to form a compressed converted binary image representation, and storing the compressed converted binary representation in a memory.

5. A method for image processing, comprising:
   scanning an image to produce a binary representation of said image at a first resolution and with a predetermined number of grayscale values;
   converting the binary representation of said image to a binary representation of an image having an increased resolution at least as great as the first resolution times the base-2 logarithm of the predetermined number of grayscale values, and having only 2 grayscale values;
   compressing the converted binary representation;
   and storing the compressed converted binary representation.

6. The method of claim 5 further comprising transmitting the compressed converted binary representation as a part of a facsimile data transmission.

7. The method of claim 6 further comprising receiving the transmitted compressed converted binary representation, decompressing the received compressed converted binary representation, and reproducing an image from the decompressed binary representation.

8. The method of claim 5 further comprising decompressing the compressed converted binary representation, and reprographically reproducing an image from the decompressed binary representation.

9. The method of claim 8 further comprising performing an inverse half-tone process on the decompressed binary representation.

10. A method for compressing binary image data having a plurality of grayscale values, comprising:
    converting the image data to a binary representation of an image having an increased resolution at least as great as the first resolution times the predetermined number of grayscale values and having only 2 grayscale values;
    and determining the grayscale values of the converted binary representation from the most significant bits of the image data.

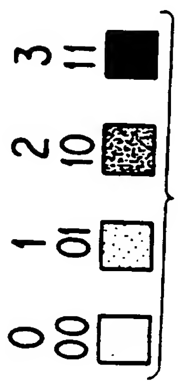

FIG. 1

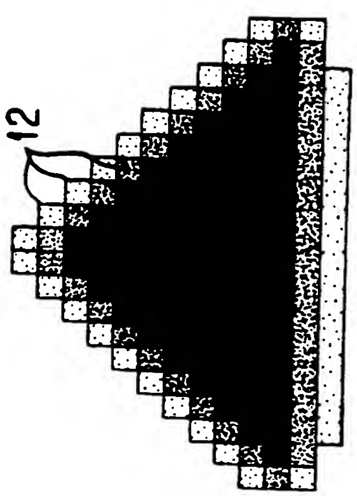

FIG. 2

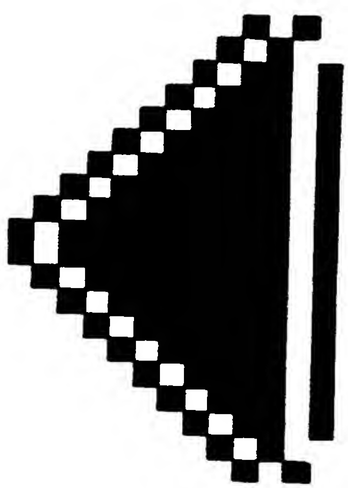

FIG. 3A
PRIOR ART

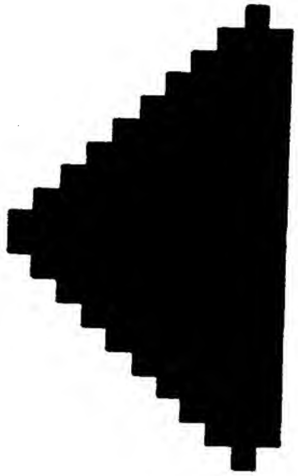

FIG. 3B
PRIOR ART

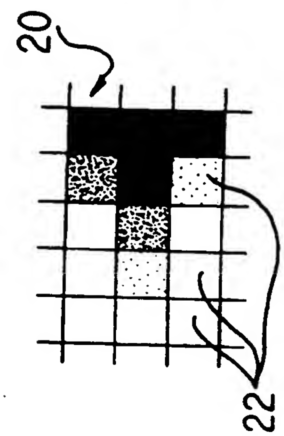

FIG. 4A

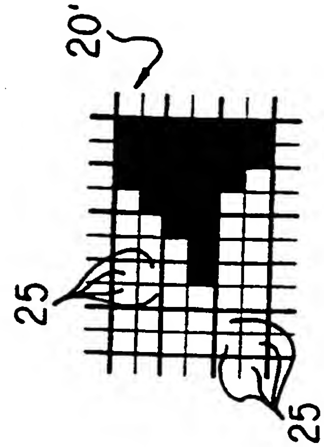

FIG. 4B

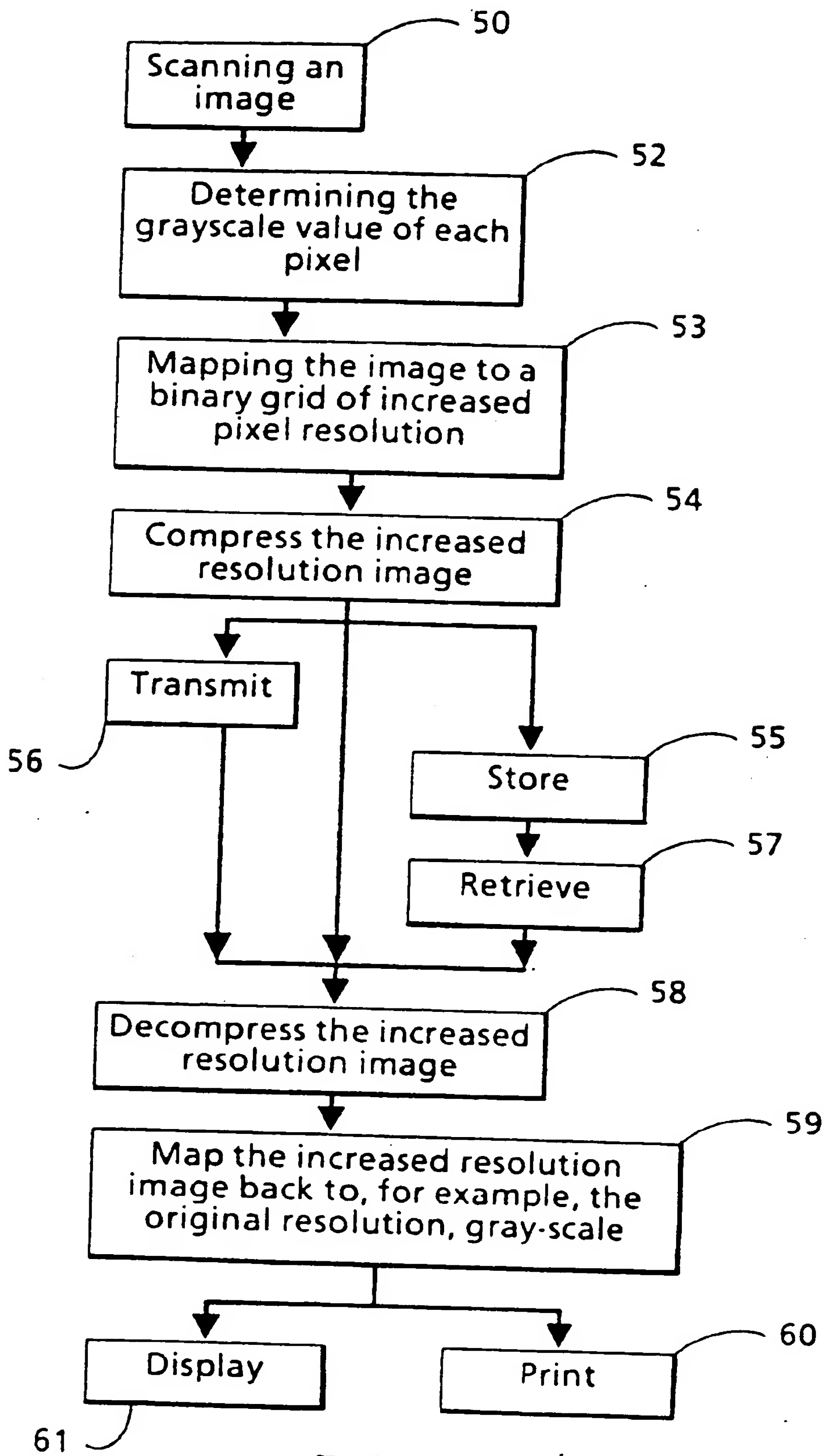
50
Scanning an image
52
Determining the grayscale value of each pixel
53
Mapping the image to a binary grid of increased pixel resolution
54
Compress the increased resolution image
Transmit
56
Store
55
Retrieve
57
58
Decompress the increased resolution image
59
Map the increased resolution image back to, for example, the original resolution, gray-scale
Display
Print
60
61

FIG. 5